

REDUCTION OF FIRE HAZARDS ON LARGE MINING EQUIPMENT

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Analysis of mining equipment fires from 1990 through 1999 reveals that there were 340 large mining equipment fires, resulting in 72 injuries and five fatalities. Many of the fires resulted in the loss of equipment and all posed potential or real risks to the operator. In 97 cases, the fires raged out of control due to engine shut-off failure, even upon activation of the machine fire suppression system, due to the spraying of pressurized hydraulic fluid and fuel onto hot engine surfaces. In other cases, even after engine shutoff, the fires re-ignited, fueled by the continued flow of flammable fluids remaining in the lines onto the hot engine surfaces. In many of the fires, flammable vapors evolved and penetrated the cab, violently igniting, forcing the operator to exit under very hazardous conditions.

The use of emergency evacuation lines in the fuel and hydraulic fluid systems, and methods to reduce or prevent the spraying of pressurized fluids onto hot engine surfaces would greatly improve the

chances of successfully suppressing large mining equipment fires. In addition, the use of systems for preventing the ignition of flammable vapors inside the cab, and detecting and suppressing fires originating in the cab, would greatly enhance operator safety. The National Institute for Occupation Safety and Health (NIOSH) recently conducted experiments on methods to reduce the fire hazards associated with large mining equipment. These experiments evaluated the use of cab inerting systems to prevent the ignition of flammable vapors inside the cab and suppress fires originating in the cab, while maintaining a breathable atmosphere for the operator to bring the equipment to a stop and safely exit the cab.

NIOSH also developed and evaluated the use of various fire barriers to prevent the spraying of hydraulic fluids and fuel onto engine hot surfaces. These methods were found to be viable additions to existing equipment detection and suppression systems that can greatly reduce large min-

ing equipment fire hazards and enhance operator safety.

Background

In the 1970s and 1980s, research was conducted by the U.S. Bureau of Mines, in cooperation with the Mine Safety and Health Administration (MSHA) and through contracts with private industry, to enhance the safety of mining equipment operators. This included the development and evaluation of engine fire detection and suppression systems¹ and fire resistant hydraulic fluids.² As a result of these research efforts, standards and regulations were developed and promulgated in the U.S. Code of Federal Regulations (CFR). However, as shown in recent analyses of mine accident data,^{3,4,5} mining equipment fires still occur with alarming frequency and grave consequences. Recent technological advances in fire protection, combined with the statistical data on equipment fires led NIOSH to reinvestigate this area to improve operator safety.

The standards and regulations developed by MSHA for fire protection of large mining equipment in underground coal mines are found in 30-CFR, part 75, and for metal and nonmetal mines in 30-CFR parts 56 and 57. In general, underground coal mine requirements are more stringent, requiring the use of fire resistant hydraulic fluid and automatic fire suppression systems. For metal/nonmetal mines and for all surface mines, MSHA permits the use of non-fire resistant hydraulic fluid and requires only fire extinguishers or manually activated suppression systems.

NIOSH analysis of the causal factors leading to large mobile mining equipment fires has shown that the leading cause is due to the spraying of pressurized hydraulic fluid and fuel onto hot engine surfaces caused by ruptured lines. It is believed that the

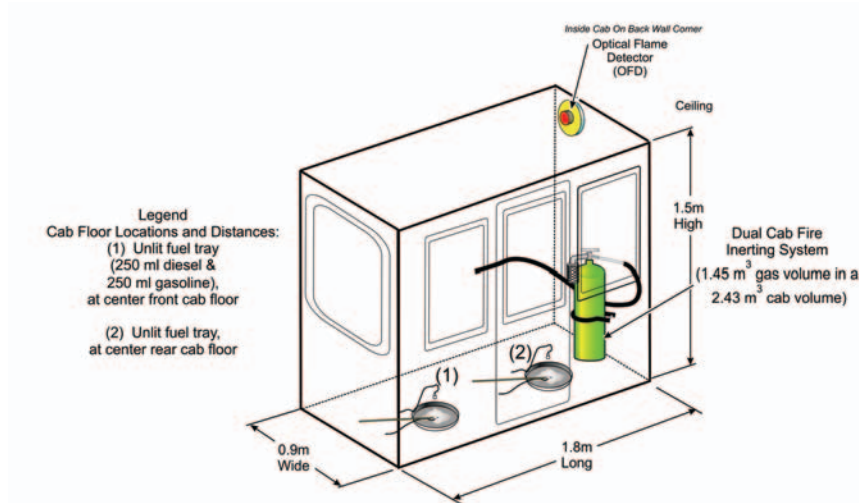


Figure 1: Schematic Illustration of the large-scale mining equipment cab with a dual cab fire inerting system discharged in the cab at typical engine fire alarm times (2 seconds) to prevent the ignition of flammable vapors and mists within the cab.

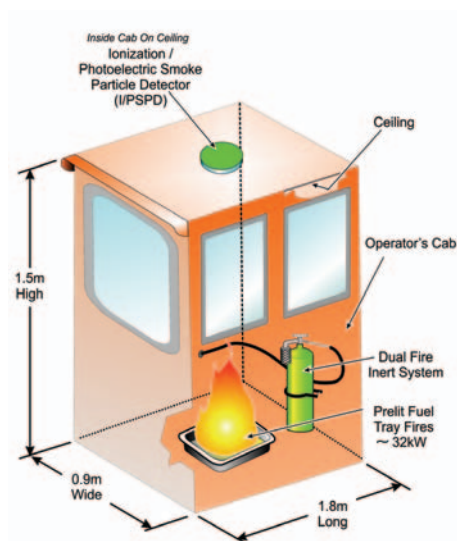


Figure 2: Schematic Illustration of the mining equipment cab. (2.66m³ volume)

number of these fires may be reduced through the adoption of existing or newly developed technologies and methodologies. These include the scheduling of more stringent inspection programs for these systems, the strategic relocation of pressurized hydraulic fluid and fuel lines, the use of stainless steel hydraulic lines and reinforced steel sleeves, the isolation and venting of hydraulic fluid compartments, the use of fire resistant hydraulic fluids for all mining equipment, the use of fire barriers and commercially available “wraps” to shield engine hot surfaces from the spraying of pressur-

ized fluids, and the use of emergency fluid evacuation lines to rapidly drain fluid remaining in ruptured lines during a fire emergency.

Recent NIOSH Research Developments

In order to reduce large mining equipment fire hazards, NIOSH recently evaluated a dual-cab fire inerting system in cooperation with the Ansul Corp., and newly developed engine compartment fire barriers.

The dual-cab fire inerting system is designed to inert the equipment cab volume to prevent the ignition of flammable vapors that may penetrate the cab during an engine fire, or suppress a fire originating in the cab, while maintaining a breathable atmosphere for the operator.^{6,7,8} This should provide the operator time to bring the equipment to a safe stop and exit the cab. The inerting system consists of a gas mixture composed of 50% nitrogen, 42% argon, and 8% carbon dioxide, contained in a pressurized vessel, and the associated detection/activation mechanism. The system can be either manually activated or activated by a flame or product-of-combustion detector located within the engine compartment and the cab, respectively. Upon activation, the gas mixture is discharged through a muffled nozzle over a period of about two minutes. A muffled nozzle reduces the noise level during discharge to 85 db and slows the discharge of the

mixture inside the cab. This allows for the slow displacement of original air (oxygen) in the cab in order to maintain a breathable atmosphere for the operator.

NIOSH evaluated the system to inert the cab in the presence of flammable vapors and to suppress a 32 kW liquid fuel fire in the cab. Schematics for the experimental set-ups are shown in Figures 1 and 2, respectively. The pressurized canister, containing 1.6 m³ of Inergen, was attached to the rear inside wall of a 2.4 m³ cab and equipped with an optical flame detector or an ionization/photoelectric smoke particle detector.⁹ It was found that this volume of Inergen gas, discharged into the cab over two minutes at a flame detector alarm of 2 s, was able to prevent the ignition of flammable vapors for three minutes, and provide a safe breathing atmosphere containing at least 12% oxygen in the cab. This is the critical time needed for the operator to safely park the equipment and exit the cab. In practice, the Inergen concentration volume needs to be engineered to the size of the equipment cab to maintain its inerting capability as well as a breathable cab atmosphere.

Experiments were also conducted with small liquid fuel fires (32 kW) in the cab. The fires, detected at a smoke particle detector alarm of 10 seconds, were suppressed within 15 seconds of initial discharge while maintaining a breathable atmosphere. These evaluations demonstrate that the use of this type of commercially available technology to protect mobile equipment cabs from fires can greatly enhance the safety of the operator.

The newly developed engine compartment fire barriers are designed to reduce the risk and severity of large mobile equipment engine fires due to the rupture of hydraulic or fuel lines.¹⁰ Oftentimes, equipment engine fires reignite after the suppression system has expelled its extinguishing agent because hydraulic fluid and/or fuel continue to be sprayed onto hot engine surfaces. The barrier concept is to shield hot engine surfaces from the spraying of fluids or isolate the fluid lines from hot engine surfaces. The barriers were shown to be quite effective in preventing or reducing the spraying of pressurized fluids onto hot engine surfaces. Various conceptualized designs of fire barriers, a one-panel and a multi-panel stainless steel insulated barriers, and an open-close steel

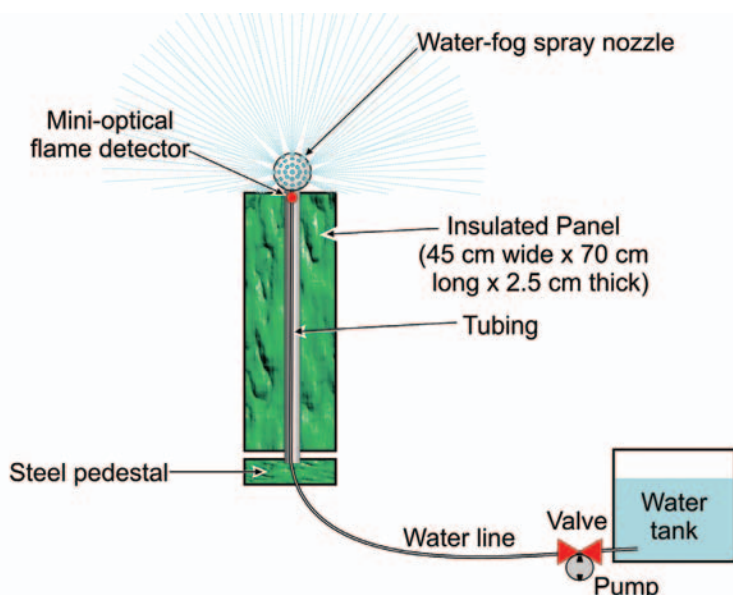


Figure 3: One-panel insulated stainless steel fire barrier with water-fog spray system.

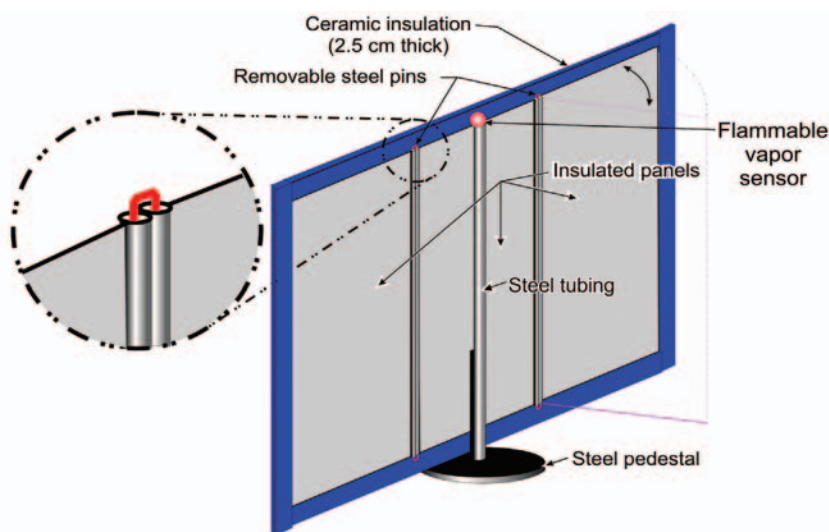


Figure 4: Multi-panel insulated stainless steel fire barrier.

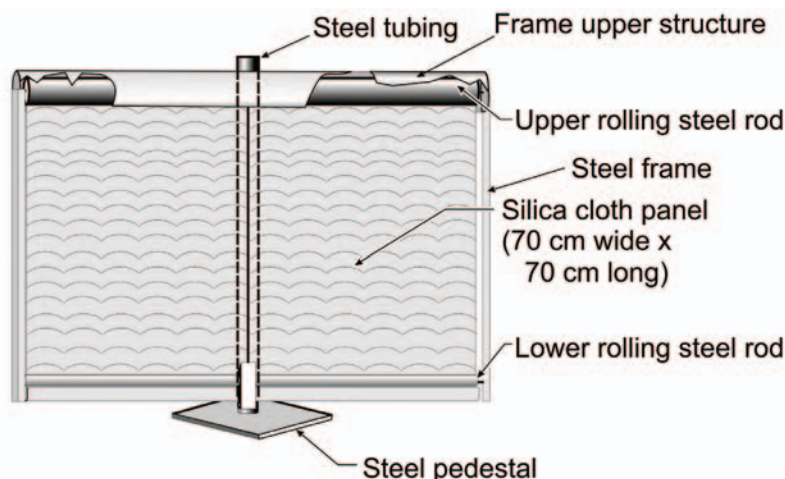


Figure 5: Rolled-up silica cloth fire barrier.

barrier, are shown in Figures 3, 5, and 6, respectively. These designs, located within the engine compartment or between the engine and the hydraulic line compartments, were equipped with mini-flame detectors, flammable vapor detectors, water-fog spray systems, and nitrogen inerting systems to demonstrate the potential for these systems to rapidly detect the engine fires, to suppress the fires, and to inert the flammable vapors within the hydraulic line compartment before they migrate to the engine compartment. In actual use, these designs would need to be automated by means of electrical control units and actuators. The open-close barrier, using a number of framed stainless steel louvers, is located between the hydraulic fluid compartment and the engine compartment. Under normal operating condi-

tions, the barrier would be open to provide cooling air to the engine. Upon detection of a fire, the louvers would close, preventing or reducing the spraying of pressurized fluids onto hot engine surfaces.

Summary

Although standards and regulations are in place to prevent large mining equipment fires, recent analyses of mine accident data show that mining equipment fires still occur with alarming frequency and grave consequences, particularly at all surface mines and in underground metal/nonmetal mines. Recent technological advances in fire protection, combined with the statistical data on equipment fires led NIOSH to reinvestigate this area to improve operator safety. NIOSH demonstrated that newly developed technologies, such as dual cab fire inerting

systems and engine compartment fire barriers can greatly enhance operator safety and lessen the damage of property during large mobile equipment fires.

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